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Sustainability Assessment Methodology of Biomass Utilization for Energy in East Asian Countries

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In response to the importance of assessing both positive and negative impacts caused by biomass utilization for energy, number of initiatives in the world are currently working on development of criteria and indicators for sustainable biomass utilization. Although there is abundant biomass to be utilized in East Asia, it is difficult to say that countries in this region are at forefront of those initiatives. In this context, in order to provide a decision-making methodology to evaluate sustainability of biomass energy utilization in East Asia, the authors were formed as an expert working group in 2007 and since then has been conducting researches to assess its sustainability with the concept of triple bottom line; namely, environmental, economic and social aspects of sustainability. In addition to the development of a methodology and indicators for sustainability assessment for biomass energy utilization, we have field-tested the applicability of the methodology in selected four East Asian countries. This paper firstly explain the methodology the working group developed, secondly the results and lessons learned from the field-tests of the methodology, and thirdly the latest works based on those lessons, aiming at comprehensive assessment of the sustainability of biomass energy initiatives at small to large scale in East Asian countries.

Key Words

Environmental, Economic and social aspects, Sustainability assessment, Biomass utilization for energy, East Asian countries

1. Introduction

It is widely recognized that biomass utilization for energy can significantly contribute to mitigation of environmental degradation, energy supply diversity and social and economic development if the biomass utilization are designed and operated in a sustainable way. This is because of the following reasons. First of all, biomass energy development provides the opportunity to enhance energy security by decreasing the dependence on fossil fuels. Secondly, biomass energy has the potential to contribute to environmental benefits mainly greenhouse gas (GHG) emissions reduction. Thirdly, biomass energy development can create job opportunity that has positive impacts on agricultural and rural development, poverty reduction and economic growth. On the other hand, there is increasing concern about Life Cycle GHG emissions of biomass energy compared with that of fossil fuels, conflict with food security and environmental degradation caused by the expansion of biomass feedstock cultivation and its use as energy. It indicates that it is important to take into consideration all the positive and negative impacts on environmental, economic and social aspects of sustainability.

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Although there is abundant biomass resource in ASEAN plus 10 countries of East Asian Summit (hereinafter referred to as East Asian countries), most of the countries in this region are dependent heavily on fossil fuel imported from other countries to meet their rapidly increasing energy demands. Governments in this region are trying to find out a variety of energy sources alternative to fossil fuels. Biomass resources for energy has emerged at that time as a sign of hope that might be able to assure social and economic benefits from employment generation through its development as well as GHG emissions reduction and energy security.

A number of initiatives in the world are currently working on development of sustainability criteria and indicators for biomass utilization for energy. In spite of abundant biomass resources in East Asian countries and some representatives in this region included in those initiatives, it is not too much to say that major initiatives are mainly led by non-East Asian countries. In order to develop a methodology to assess sustainability of biomass energy utilization suited to the East Asian countries, it is urgently required to discuss the sustainable biomass utilization for energy in this region where social and economic situations are quite diverse.

In this context, the authors were formed from researchers of East Asian Countries as an expert working group in 2007 under the support of Economic Research Institute of ASEAN and East Asia (ERIA) and have been conducting studies on the sustainability assessment of biomass utilization for energy. In the working group's discussions in 2007 on "Sustainable Biomass Utilisation Vision in East Asia"[2], we suggested policy recommendations and framed "Asian Biomass Energy Principles", which were endorsed by the Energy Ministers Meeting of East Asian Summit at Bangkok in August 2008. In response to the request from Energy Ministers of the region to develop a methodology to assess the environmental, economic and social impacts of biomass utilization for energy by taking into account specific regional circumstances, the working group started investigations toward "Guidelines for Sustainability Assessment of Biomass Utilisation in East Asia"[3] in 2008, in which the working group identified indicators for each aspect of sustainability. Subsequently in 2009, the working group field-tested the guidelines in four pilot studies, which were conducted at India, Indonesia, Thailand and the Philippines and investigated the sustainability of a variety of biomass feedstocks utilization for energy [4].

Although the applicability of the indicators was proved by the pilot studies, it turned out that extensive data collection was required for use of all the indicators and interpretation of results. On the basis of the working group's lessons learned from the four pilot studies, in 2010-2011 the working group discussed the applicability of the indicators and proposed the candidate indicators to comprehensively assess three aspects of sustainability of biomass energy utilization for both small and large scale initiatives.

This paper summarizes the outcome from the working group activities mentioned above. It firstly explains the methodology developed, secondly the results and lessons learned from the field-tests of the methodology, and thirdly the latest works based on those lessons learned, aiming at comprehensively assessing the sustainability of biomass energy initiatives at small to large scale in East Asian countries.

2. Working Group Methodology to Assess Sustainability of Biomass Utilization in East Asia

This chapter explains the methodology developed by the working group to assess sustainability of biomass utilization for energy in East Asia.

2.1 Definition of Sustainability

As the definition of sustainability, the working group chose "sustainable development" from "Our Common Future" of the United Nations World Commission on Environment and Development report [5] where it describes "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". It also mention that the triple bottom line approach focusing on "people, planet, profit" is based on social, environmental and economic criteria. To ascertain the sustainability of biomass energy development, these aspects are essential and must be taken into consideration to overcome and minimize the problems that may occur with the expansion of biomass energy utilization. Hence with respect to environmental, economic and social aspects, the working group had set out to develop a methodology to assess the sustainability of biomass utilization in the East Asia. Each indicators in the three aspects are summarized in 2.3.

2.2 Target Users of the Methodology

Since the working group methodology is designed to be applied in East Asian countries to assess sustainability of biomass utilization for energy, the methodology would be used for a biomass utilization project being planned or in operation in order to analyze the sustainability of the project. It would be also used for comparative analysis on sustainability of several options of a biomass project. In those cases, users of the results obtained through the use of the methodology are supposed to be the decision makers who have the right to make decisions on whether or not the biomass utilization initiatives should be introduced/carried on, including politicians in charge of biomass project policy and stakeholders such as owners of farms or plantation fields, factory managers, etc. On the other hand, direct users of the methodology, who will be asked by decision makers to assess the sustainability of biomass initiatives and to report the results of the assessment to them, would be academics, consultants and technical officers.

2.3 Environmental, Economic and Social Indicators

The working group has chosen one indicator for each aspect of sustainability as tabulated in Table 1. The environmental, economic and social indicators are explained in 2.3.1 to 2.3.3.

2.3.1 Environmental Indicator

Life cycle assessment (LCA) is increasingly becoming an important tool for analyzing and assessing the environmental performance of a product system. One of the LCA procedures is standardized in ISO14040s. It is suited to environmental decision making and evaluation of the overall environmental impacts of a product system throughout its "cradle to grave" lifecycle. The LCA can be applied to quantitatively assess a variety of impact categories caused by a product system such as climate change, acidification, eutrophication, photo-oxidation, toxicity and biodiversity loss. Although other impact categories are important for biomass utilization for energy, climate change among them is the world's concern and associated with the increasing frequency of extreme weather conditions and disasters, which would affect all the countries including East Asia. Effects of climate change have been attributed directly to the increased atmospheric concentration of GHG released by anthropogenic activities. The working group, therefore, adopted life cycle GHG emissions as the indicator to evaluate the environmental sustainability of biomass utilization for energy. The life cycle GHG emissions can be quantified through life cycle inventory (LCI) analysis by way of the collection of foreground and background data associated with a product system. The system boundary of biomass energy utilization consists of three stages; namely, feedstock cultivation, feedstock collection and biomass energy production.

Table 1 Sustainability Assessment Indicators of the Working Group Methodology in 2008

Indicator	Index
Environmental	GHG Savings
Economic	Total Value Added
Social	Human Development Index

The LCI for biomass energy should cover carbon dioxide and non-carbon dioxide GHGs, namely methane and nitrous oxide that are released directly and indirectly from agricultural activities and processing of agricultural products. The GHG inventory is calculated in the unit of carbon dioxide equivalent weight of greenhouse gases (kg-CO_2eq or tons- CO_2eq). The summation of contribution from non-CO_2 GHGs are computed by Equation (1), based on Global Warming Potential (GWP) values for a 100 year horizon [7] of the IPCC Fourth Assessment Report (AR4).

$$LCGHG = \sum_{i,j} (GHG_{i,j} \times GWP_i) \tag{1}$$

where

i : a greenhouse gas, e.g. carbon dioxide, methane and nitrous oxide.

j : a stage consisting of the life cycle of biomass utilization for energy, e.g. feedstock cultivation, feedstock collection and biomass energy production.

FU : Functional Unit, e.g. per hector per year, per 1 kilo litter or GJ of biofuel, etc.

$LCGHG$: Life Cycle GHG emissions [kgCO_2eq/FU].

$GHG_{i,j}$: Quantity of a GHG 'i' in a stage 'j' [kgCO_2eq/FU].

GWP_i : Global Warming Potential for a greenhouse gas 'i'.

In assessing sustainability of biomass energy utilization, it is important to determine whether the GHG emissions of bioenergy are smaller than those of the fossil fuel based energy as a first step. This may be tested by calculating GHG savings as shown below.

$$S = LCGHG_{Fossil} - LCGHG_{Bioenergy} \tag{2}$$

where

S : GHG savings as bioenergy replaces fossil-based energy.

$LCGHG_{Fossil}$: Life Cycle GHG emissions from fossil fuel based energy.

$LCGHG_{Bioenergy}$: Life Cycle GHG emissions of bioenergy.

2.3.2 Economic Indicator

Economic sustainability of biomass utilization relates to the exploitation of biomass resources in a manner by which the benefits derived by the present generation are obtained without depriving such opportunity to the future generations. In the assessment of sustainability, it is equally important to determine the actual level and degree of the economic benefits brought about by the biomass industry. Specific economic indices would have taken into consideration to measure the scope of the benefits. Existing methodologies in quantifying such indicators would have to be adopted and evaluated as well. Economic indicators ultimately provide an accurate measurement of the economic performance of a particular industry such as biomass. Based on the various literature reviewed, the most common economic contributions of biomass utilization are value addition, job creation and tax revenue generation. The same indicators were taken into consideration to evaluate economic sustainability of biomass energy utilization in the working group methodology: 1) total net profit accumulated from product conversion or processing; 2) personal remuneration created by employment at the biomass industry; 3) tax revenues generated from the different entities within the industries; and 4) total value added, which is the sum of all the previous indicators. Each indicator can be calculated by the following equations:

Total Net Profit (TNP)

$$\textit{Total net profit} = \textit{Total returns} - \textit{Total costs} \quad (3)$$

where

$$\textit{Total returns} = \textit{Sales from primary output} + \textit{Sales from by-products}$$

$$\textit{Total costs} = \textit{Amount of material inputs used} + \textit{Labor costs} + \textit{Overhead costs}$$

$$\textit{Overhead costs} = \textit{Taxes and duties} + \textit{Interest} + \textit{Depreciation}$$

Personal remuneration

$$\textit{Personal remuneration} = \textit{Total man-days (Employment)} \times \textit{Average wage per man-days} \quad (4)$$

where

$$\textit{Wages} = \textit{Wage rate} \times \textit{Labor requirement}$$

Tax Revenue

$$\textit{Tax revenue} = \textit{Total taxable income} \times \textit{Tax rate} \quad (5)$$

where

$$\textit{Total taxable income} = \textit{Income from main product} + \textit{Income from by-product}$$

$$\textit{Income from main product} = \textit{Profit per unit of main product } A \times \textit{Volume of } A$$

$$\textit{Income from by-product} = \textit{Profit per unit of by-product } B \times \textit{Volume of } B$$

Total Value Added (TVA)

$$\textit{Total value added} = \textit{Total net profit} + \textit{Personal remuneration} + \textit{Tax revenue} \quad (6)$$

2.3.3 Social Indicator

Social issues in the growing markets for biomass energy utilization are expected to become prominent as the producers and consumers of biomass energy may belong to different countries. Major positive social impacts of biomass energy include enhancing energy security, creating job opportunities, etc. On the other hand, negative social impacts expected in biomass energy utilization are food insecurity, land use conflicts with indigenous inhabitants, exploitative working condition, etc. To capture the holistic picture of development across countries, the United Nations Development Programme (UNDP) has used the Human Development Index (HDI)[8]. This essentially takes into account the measures for living a long healthy life (by life expectancy), being educated (by adult education and enrolment at primary, secondary and tertiary levels) and having a decent standard of living (by purchasing power parity, PPP). The working group adopted HDI as the indicator to evaluate social sustainability of biomass utilization for energy. The calculation of HDI can be described as equation (7).

$$HDI = \frac{1}{3}(LE + EDU + GDP) \quad (7)$$

LE : Life Expectancy Index

$$\textit{LE index} = (LE - LE_{min})/(LE_{max} - LE_{min})$$

EDU : Education Index

$$\textit{EDU index} = \frac{2}{3} \times ALI + \frac{1}{3} \times GEI$$

where

ALI (Adult Literacy Index)

$$= (ALR - ALR_{min})/(ALR_{max} - ALR_{min})$$

GEI (Gross Enrolment Index)

$$= (GER - GER_{min})/(GER_{max} - GER_{min})$$

Note:

ALR: *Adult Literacy Rate* [%]

GER: *Gross Enrolment Ratio* [%]

GDP : GDP Index

$$\text{GDP Index} = \frac{\ln(GDP) - \ln(GDP_{\min})}{\ln(GDP_{\max}) - \ln(GDP_{\min})}$$

Where

GDP: GDP (PPP) per capita [USD]

3. Applications of the Methodology in the Four Pilot Studies

Four pilot studies had been carried out in India (Andhra Pradesh), Indonesia (Lampung), the Philippines (Quezon) and Thailand (Khon Kaen) in order to apply and field-test the working group methodology for sustainability assessment of biomass energy utilization in East Asia.

Table 2 summarizes the types of feedstocks and final products, and the results of respective indicators in each pilot study. Every pilot study required more than hundred sets of data for the use of environmental, economic and social indicators as shown in Table 3. The data were obtained through interviews, calculations based on primary data collected from pilot study sites, and secondary data from elsewhere. The results of each pilot study are briefly

Table 2 Summary of the results of the four pilot studies

	India	Indonesia		Philippines	Thailand
	Jatropha for Biodiesel	Jatropha for Oil	Cassava for Bioethanol	Coconut for Biodiesel	Sugarcane for Bioethanol
Environment GHG Savings (Life Cycle GHG Emissions)	1,668 (2.7 million) t-CO_2eq/yr	(12.6) kg-CO_2/GJ	(12.7 - 88.9) kg-CO_2eq/GJ (Depending on Methane Treatment)	2.82 (1.27) t-CO_2eq/ha/yr	42.0 thousand t CO_2eq/yr (124 kg-CO_2eq/t-cane)
Economic Total Value Added (Total Net Profit)	1,674 USD/ha/yr	(157) USD/ha/yr	0.103-0.120 USD/L-Bioethanol	305 million USD in the province	116 million USD/yr
Social HDI at the project site	0.616	0.541	0.560	0.784	0.736-0.797

Note: The results cannot be compared among the studies as their scope, feedstock and products are different from one another.

Table 3 Raw data required for calculating sustainability assessment indicators

Indicators	Data required
Environmental	'Cradle to Grave' inventory of inputs of diesel, electricity, fertilizers and chemicals, and outputs of byproducts and bioenergy, etc.
Economic	Production costs, yield output, market price of output, job creation per ton of a final product, tax collected, etc.
Social	Life expectancy, adult literacy, GDP, etc. in the region where the project was carried out.

summarized here. More detailed data can be found in the working group report [4].

3.1 Pilot Study in Andhra Pradesh, India

Economic assessment indicates that cost incurred in the Jatropha cultivation stage is much higher than the revenue generated. It indicates that the Jatropha cultivation is not economically viable. On the other hand, at the biodiesel production stage, both total value added (TVA) and total net profit (TNP) are quite attractive if the raw material is available at a reasonable price. In the whole biodiesel production chain, the study estimated TVA and TNP at 1,674 USD and 824 USD per hectare per year respectively. On the environmental aspect, the total GHG savings were estimated at 2,771,681 t-CO_2eq per year. On the social aspect, several positive changes in HDI are visible during various stages of biodiesel production. The main factor is employment generation for local people, which may result in their income increase, and then ultimately an overall improvement in their living standard.

3.2 Pilot Study in Lampung, Indonesia

In the case of cassava for ethanol, the results of environmental assessment show that the Life Cycle GHG emissions from the bioethanol production stage greatly depend on whether methane released from wastewater treatment is burnt or not. If the methane is utilized or just flared, the Life Cycle GHG emissions is about one thirds of those in the case where the methane is released into the air. Economic assessment indicates that processing cassava for bioethanol increased the total value added of cassava by about 0.103-0.120 USD per liter of bioethanol. For social assessment, the HDI values for cassava farmers in the study region were estimated to be lower than those in the whole North Lampung. As indices of both Life Expectancy and Education are nearly constant for a short period, main factor dominant for the change in HDI value is GDP index, which heavily depends on cassava price.

In the case of Jatropha biodiesel, the farmers in the study village receive a very low benefit from the cultivation due to a very low selling price of Jatropha seed. However, utilization of wastes, namely Jatropha seed cake for biogas production and sludge for fertilizer increased their earnings significantly. The result of environmental assessment indicates that the GHG emissions from the stages of Jatropha cultivation and crude Jatropha oil processing were 59% and 82% of the total emissions, respectively. Biogas production from Jatropha cake was found out to be 41% of the GHG emissions reduction. The results of social assessment show that Jatropha farmers in the North Lampung were lower in HDI, indicating that their quality of lives are lower than those for the people in the whole North Lampung.

3.3 Pilot Study in Quezon, the Philippines

The lifecycle of Coconut Methyl Ester (CME: biodiesel from coconuts) production is composed of stages of coconut cultivation, copra processing, crude coconut oil production and CME production. The results of economic assessment shows that the total net profit per unit of product is highest for copra production (at 0.150 USD per kg) and lowest for CME production (at 0.0027 USD per litre). The TNP for the whole CME production chain is about 844 USD per ha and the TVA from the CME industry in the province of Quezon would be or 305 million USD. The use of CME to replace petro diesel will result in GHG savings of 2,823.97 kg-CO_2eq per ha per year. In social assessment, the computed HDI of the whole CME production chain is 0.784, which is 0.004 higher than that of Philippines. It indicates a higher level of social development than the average. In terms of living standard, the majority (66%) of coconut farmers perceived that there has been an improvement in their living conditions due to coconut farming. In general, the results show that majority of the employees benefited from their respective employment in the CME production chain.

3.4 Pilot Study in Khon Kaen, Thailand

Environmental assessment for the lifecycle of ethanol production indicates that the overall GHG emissions associated with the ethanol production and consumption stages are slightly lower but not significantly different from that of gasoline. Increasing the utilization of the materials produced during various unit processes in the biorefinery complex results in reducing the GHG emissions. Economic assessment of the overall process of bioethanol production indicates that the TVA for the whole biorefinery complex amounts to 116,108,080 USD and it is economically viable. For social assessment, the HDI of the sugarcane plantation, biorefinery complex, and Khon Kaen were observed as 0.736, 0.797 and 0.763, respectively. Thus, although sugarcane farmers have a lower social development than an average person in Khon Kaen or employee at the biorefinery complex, they still benefit from a steady income as a result of the contract farming, which links them to the sugar mill and guarantees an annual income. Employees at the biorefinery have a higher social development (shown by a positive change of 0.034 in HDI) as compared to the Khon Kaen.

4. Discussions

The application and field-testing of the working group methodology of sustainability assessment in the selected four East Asian countries revealed that the methodology could successfully quantify the sustainability of biomass energy utilization projects in terms of three aspects of sustainability component; environmental, economic and social aspects. However, through the experience from the field-testing, the working group has found out that some modifications may be required for the methodology. Among a number of lessons learned from the pilot studies, the noteworthy points found from the whole pilot studies are taken up in this chapter.

4.1 Environmental Aspect

Through the pilot studies conducted in the four sites, the working group confirmed high applicability of the environmental indicator, GHG emissions, with the use of LCA.

However, several important issues were identified. First of all, as shown in Chapter 3, some vital components of LCA such as scope of the study or functional unit defined in each pilot study are different from one another. This is because the biomass project investigated in the studies were significantly diverse in scale and characteristics e.g. a biomass feedstock planting small village to a large-scale biorefinergy complex. It makes it difficult for us to extract meaningful findings from the whole studies at a glance. Those vital components need to be carefully considered and then may be standardized for assessments of biomass energy utilization, particularly for comparative analysis with different feedstock, biomass energy or technology. Secondly it is noted that the foreground data in most cases were primary data obtained directly from the stakeholders. As biomass energy namely biofuels are new industries or new applications of biomass in all the four studies, most data sets may not be representative of situations. Based on the available data collected, qualitative assessment of the representativeness of the data in terms of geographical coverage, time period and technology coverage should be highlighted especially for a report that will be used for decision-making eventually.

Another concern in estimating GHG emissions is that the working group methodology currently does not take GHG emissions from Land Use Change (LUC) into account because all the four pilot study sites were not converted from land with high carbon stock in the last few decades. However, the working methodology should mention this impacts as it is widely discussed that the impacts of LUC on the life cycle GHG emissions from biomass energy utilization could be dominant particularly in areas with high carbon stock. The emissions can be calculated using equations and default values provided by the Guideline of the International Panel on Climate Change [6] with a large uncertainty in the calculation results. Although this uncertainty can be reduced by directly measuring carbon in soil and above/below biomass (that are components for the calculation of GHG emissions from LUC) in an area to study, it requires years of measurement of those values. IPCC studies are now on-going and expected to provide more accurate default values with scientific evidence, which would be adopted in our methodology in future.

The working group recognizes from the beginning that the environmental impact caused by biomass energy utilization is not only climate change induced by GHG emissions. The pilot studies highlighted again the importance of other environmental impact categories, particularly impacts on air, water and soil quality, and water resources, influence on ecosystem service (e.g. biodiversity), issues associated with both direct and indirect LUC, net energy balance, abiotic resources depletion, eutrophication and acidification.

4.2 Economic Aspects

The economic indicators in most of the pilot studies showed positive results, indicating that in these cases the biomass utilization projects were economically viable. However, as shown in Table 2, a single indicator with a subcomponent alone is not sufficient to explain the whole picture of economic sustainability. In order to better analyze and understand economic sustainability, it is necessary to focus on all the three subcomponents of the TVA together at the same time.

TNP is more of business concern; wages derived from employment is for the labourers; while tax revenue generated is for the local and national government. A high TNP alone will not ensure the sustainability of the production nor the high wage of the employees/labourers and also of the high tax paid to the government. The sustainability of biomass utilization for energy like biofuel production should be an attractive business in terms of all the three subcomponents of economic indicator. Hence the positive impact of all the three sub-indicators must be present.

4.3 Social Aspects

Although HDI is an appropriate indicator that takes into account three essential end-point component of social aspect, there were difficulties in implementing the assessment. Calculation of HDI was data intensive, requiring inputs on a wide array of parameters, however, the pilot studies found that those data were not readily available at the village or district level. In addition it seems difficult to isolate the impact of a biomass project alone, particularly at community level. This is because HDI is more suitable for large scale assessment of social development and raking purposes. To assess community level, the more directly measurable social parameters are, for example, employment opportunity, stability of income, income increase, education for the children, health condition, relationship in the plant or community among others, energy diversity, access to modern/clean energy/electricity, employment, food security, land allocation and tenure, policy enforcement and change in the consumption of fossil fuels/traditional use of biomass.

On the other hand, some other parameters that should be seen in national level are energy security and, food security.

5. Methodology Upgraded Based on the Lessons Learned

Based on the lessons learned and taking into account the latest worldwide discussions for bioenergy sustainability, the working group upgraded the methodology. It has dealt first with the issues arising from the difference in scale of biomass projects that were mainly discussed in social aspect, so that the indicators in all the three aspects could apply small to large sized biomass energy utilization initiatives. As in the pilot studies there were no biomass project at large scale e.g. province or national scale, the working group discussed and rechecked the applicability of the methodology for small to large sized projects. This upgrade for the methodology is summarized in Fig. 1. Secondly the working group examined the components that were not sophisticated or covered in the methodology so that the decision makers could use it as a more scientific and practical tool. All the upgrade above are explained in detail in the following sections.

5.1 Environmental Indicators

The environmental indicator, Life Cycle GHG emissions, could be applied to projects at bigger scale e.g. district, state or province and national scale. The difference between applying the methodology at small and large scale is mainly in the data collection, data treatment and data integration at the stage of inventory data preparation. Data collection will be more intensive and averaging the raw data sets may be more suitable for large scale initiatives.

The field-testing results pointed out that there were large difference in the vital components of LCA such as functional unit or scope of the study. To cope with this issue, it is recommended that the estimation should carefully follow not only LCA 14040s but other internationally accepted methodologies, some of which are well-tailored to calculating GHG emissions.

The other issue in environmental indicator is that the environmental sustainability of biomass utilization for energy is measured not only by global warming intensity. Other impact categories are also important and can be quantified by LCA particularly in biomass utilization sites where a specific environmental category is of great concern.

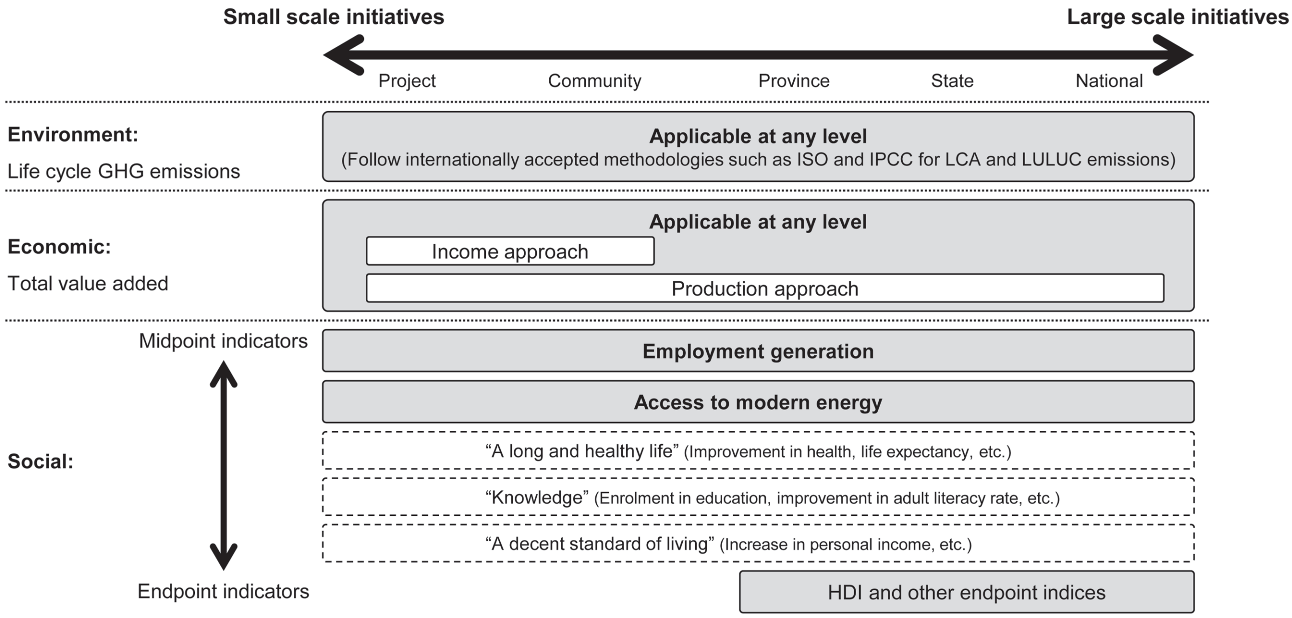

Fig. 1 Indicators of Sustainability of the upgraded methodology

5.2 Economic Indicators

TVA can be applied to any scale of biomass utilization initiatives to quantify economic sustainability. For small scale initiatives at the community or project levels, the income approach can be used to add up all the income earned by the project or in the community. On the other hand, the product approach that calculates the market value of goods and services produced in the economy can be applied to both small and large scale initiatives.

As discussed in Section 4.2, in order to capture the whole picture of economic sustainability, the subcomponents of TVA have important implications. The upgraded methodology hence takes into consideration both a master indicator and sub indicators. The master indicator is TVA that is used for any project whereas the sub indicators are Labor Income, Net Profit, Tax Revenue and Foreign Exchange Savings that are used wherever they are concerned.

5.3 Social Indicator

As discussed in Section 4.3, HDI may be only applicable for large scale biomass utilization initiatives. In order to quantify the social impact of biomass utilization at small scale initiatives, more directly measurable (midpoint) indicators are relevant to capture local impacts. The ones selected for small initiatives as master indicators of social sustainability are employment generation or personal income, and access to modern energy.

Employment generation or personal income is a vital midpoint social indicator that could trigger many other endpoint social impacts such as higher education, quality of life, etc.

On the other hand, access to modern energy can be also an important social indicator, which could be measured in terms of number of households or communities provided with that access. In the Asia-Pacific region, almost a billion people are currently far away from access to electricity. In addition, energy consumption has a correlation with poverty, deprivation, etc. Biomass energy utilization project in remote and rural areas may make it possible for those people to access to energy.

In addition to the indicators above, some other important factors that may affect social change due to the use of biomass energy were observed in the four pilot studies. Although some of them may not be quantified, a methodology to assess those impacts requires further studies.

6. Concluding Discussion and Way Forward

The final goal of the working group project is to propose an academically-sound and practically-relevant methodology to assess sustainability of biomass utilization for energy in East Asian countries in line with worldwide trends of growing concern about biomass sustainability so that it can contribute to policy making particularly on how biomass utilizations should be implemented in each country in a sustainable way.

Although the working group proposed the methodology upgraded based on the lessons learned from the four pilot studies, continuous plan-do-check-act (PDCA) cycle is essential to calibrate and improve the methodology. In addition, since East Asian countries are abundant in biomass resources, the biomass feedstocks for energy are not limited to Jatropha, cassava, coconut and sugarcane.

Sustainability of biomass initiatives on other kinds of feedstock such as oil palm and other oil trees or cellulosic biomass are also needed to be evaluated with the methodology. Even though the same feedstock was chosen in different initiatives, the results of the sustainability assessment would vary with technologies adopted in the energy conversion processes or the size of the initiatives. Hence the working group is currently planning to accumulate the research experience by conducting case studies with use of the upgraded working group methodology and evaluate the sustainability of both small and large scale biomass energy initiatives with a variety of feedstocks in East Asian countries.

7. Conclusion

In this paper, the working group methodology of biomass utilization for energy in East Asia was firstly addressed with the concept of the triple bottom line, namely environmental, economic and social aspect of sustainability. The indicators to assess each aspect of sustainability were selected and then field-tested in the plot studies conducted in four countries; India, Indonesia, Philippines and Thailand. The applicability of each indicator was confirmed and some issues were found to be needed to modify. The results and lessons learned from the four pilot studies were carefully discussed, and then the methodology was upgraded so as to assess sustainability of wider range of projects, i.e. small to large initiatives.

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